

1.221J/11.527J/ESD.201J *Transportation Systems*

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LECTURES 2 & 3

DISPLAYS

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TRANSPORTATION AND THE SOCIAL-POLITICAL-ECONOMIC CONTEXT

- ◆ Public-Policy Lever
- ◆ Private-Sector Investment
- ◆ Industrial Base (e.g., auto and shipbuilding industries)
- ◆ Economic Development
- ◆ Employer
- ◆ Large-Scale Infrastructure with long-term Impact
- ◆ Environmental Impact -Sustainable Systems
- ◆ Energy Issues
- ◆ Equity Issues

TRANSPORTATION SYSTEM – INTERNAL COMPONENTS

- ◆ Physical system
- ◆ Management
- ◆ Labor

TRANSPORTATION PHYSICAL SYSTEM COMPONENTS

- ◆ Infrastructure
 - ◆ Guideway
 - ◆ Terminals
 - ◆ Stations
- ◆ Vehicles
- ◆ Power Systems
- ◆ Fuel
- ◆ Control, Communications & Location Systems

Figure 2.1

INFRASTRUCTURE

- ◆ **Guideways: Special Purpose vs. General Purpose Guideway -- some examples**
 - ◆ Highway
 - ◆ Railroad
 - ◆ Pipeline
 - ◆ Air Corridors
- ◆ **Terminals/Stations -- some examples**
 - ◆ Rail Freight Yards
 - ◆ Container Port
 - ◆ Airports
 - ◆ Bus Stations
 - ◆ Transit Stations
 - ◆ Street Corner Bus Stops/Taxi Stands

VEHICLES

- ◆ Automobiles
- ◆ Rail Locomotives
- ◆ Airplanes
- ◆ Tractor Trailer
- ◆ Truck Trailers
- ◆ Railroad Cars
- ◆ Containers

VEHICLE CHARACTERISTICS

- ◆ Crashworthiness
- ◆ Degree of Automation
- ◆ Energy Source: internal vs. external
- ◆ Weight
- ◆ Material
- ◆ Aerodynamics
- ◆ Emissions

EQUIPMENT -- SOME EXAMPLES

- ◆ Loading Crane at Container Port
- ◆ Railroad Track Maintenance Equipment
- ◆ Airport Baggage Handling
- ◆ Snow Removal Vehicles

POWER SYSTEMS

- ◆ Internal Combustion Engine
- ◆ Diesel Engine
- ◆ Electric Motors
- ◆ Hybrid Engines
- ◆ Fuel Cells
- ◆ Humans
- ◆ Animals
- ◆ Gravity
- ◆ Windmill
- ◆ Solar Panels
- ◆ Tidal Baffles

FUEL

- ◆ Gasoline
- ◆ Natural Gas
- ◆ Diesel
- ◆ Coal
- ◆ Electricity (e.g., as generated from coal)
- ◆ Electricity (as in an onboard battery)
- ◆ Solar Energy
- ◆ Tides/Currents
- ◆ Wind
- ◆ Hydrogen

CONTROL, COMMUNICATIONS AND LOCATION SYSTEMS

- ◆ Humans
 - ◆ Driver
 - ◆ Controllers (as in air traffic)
 - ◆ Dispatcher
- ◆ Technology
 - ◆ Traffic Lights
 - ◆ Sensors -- e.g., Loop Detectors
 - ◆ Fleet Management Systems
 - ◆ Automated Vehicles
 - ◆ Block Control (railroad)
 - ◆ Global Positioning Systems (GPS)
 - ◆ Intelligent Transportation Systems (ITS)

SUMMARY -- TRANSPORTATION PHYSICAL SYSTEM COMPONENTS

- ◆ Infrastructure
 - ◆ Guideway
 - ◆ Terminals
 - ◆ Stations
- ◆ Vehicles
- ◆ Power Systems
- ◆ Fuel
- ◆ Control, Communications & Location Systems

MANAGEMENT (I)

- ◆ Marketing: why do customers want...?
 - ◆ Intramodal
 - ◆ Intermodal
 - ◆ Intersectoral (e.g., transportation vs. communication)
- ◆ Planning
 - ◆ Strategic planning (e.g., building the network, buying the vehicles)
 - ◆ Operations planning (e.g., creating an operations plan)
- ◆ Operations
 - ◆ Distinct from operations planning (e.g., actually running the system)

MANAGEMENT (II)

- ◆ Maintenance Management
- ◆ Information Management
- ◆ Operations Research
- ◆ Administration

OPERATIONS/MARKETING “TENSION”

- ◆ Marketing people like to provide high-quality service. To a first approximation, they want to maximize revenues.
- ◆ Marketing people like to provide universal, direct, frequent, and high-quality service to transportation customers.
- ◆ Marketing people are basically concerned with maximizing the revenues that flow to the company.

OPERATIONS/MARKETING “TENSION”

- ◆ Operations people are cost-oriented.
- ◆ Operations people are typically worried about minimizing cost.
- ◆ Operations people want to run an efficient and cost-effective operation.

OPERATING PLANS

- ◆ Schedule
- ◆ Crew Assignments
- ◆ Vehicle Distribution
- ◆ Connections
 - ◆ Intermodal
 - ◆ Intramodal

CONNECTION PATTERNS -- HUB-AND-SPOKE

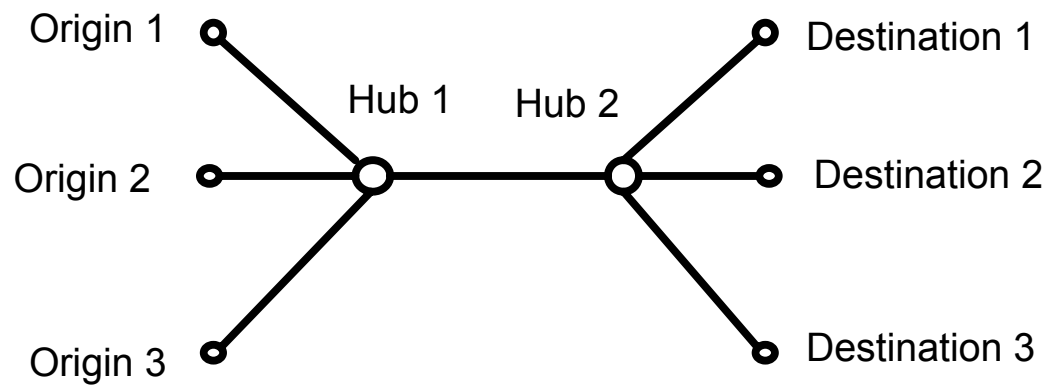
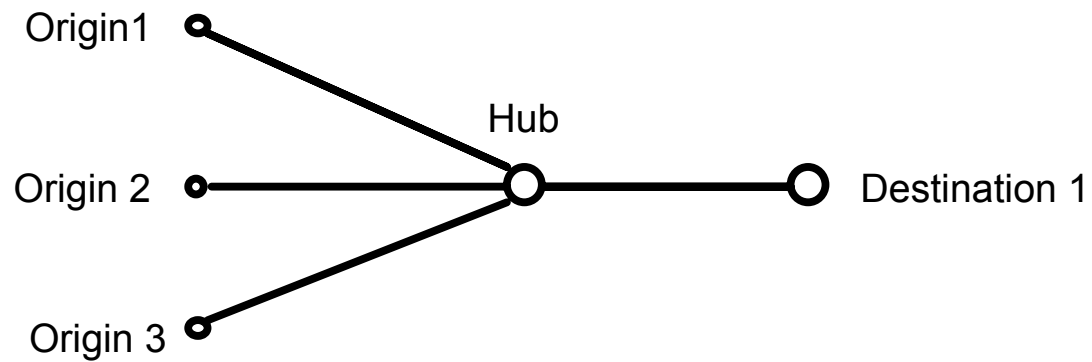


Figure 2.2

COST/LEVEL-OF-SERVICE TRADE-OFF

Two Connection Patterns

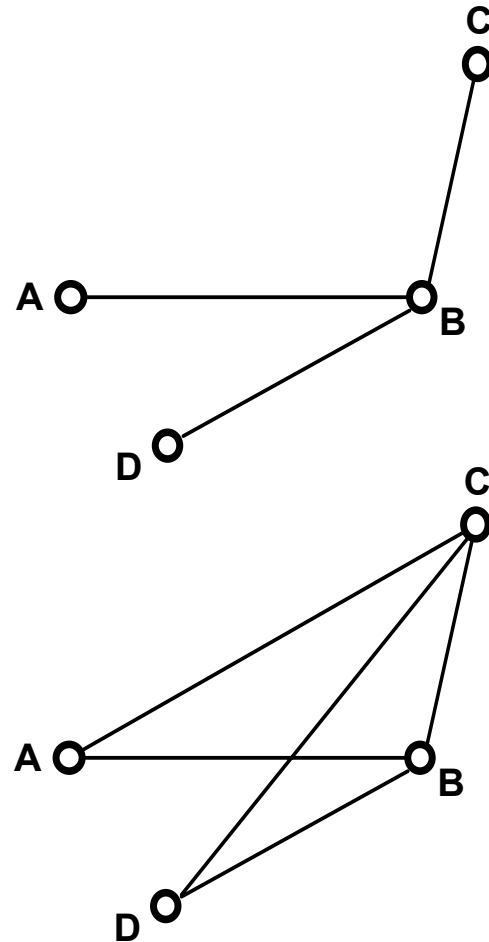


Figure 2.3

Do we provide direct, high-quality service from A to C as shown in the lower figure, or do we consolidate passengers at Node B with other passengers from Node D, into a single flight from B to C?

Here we have some fundamental *cost/level-of-service trade-offs*.

Which pattern does the VP-Marketing like?
How about the VP-Operations?

CONTINGENCY PLANNING

What do we do when things go wrong? How do we decide how to alter our operating plan to reflect changes in weather, demand for service and accidents -- such as a derailment?

LABOR

- ◆ Drivers
- ◆ Dispatchers
- ◆ Fare collectors
- ◆ Mechanics
- ◆ Union vs. non-union

**TRANSPORTATION
SYSTEMS COMPONENTS:
AN EXTERNAL
PERSPECTIVE**

EXTERNAL COMPONENTS OF THE TRANSPORTATION SYSTEM

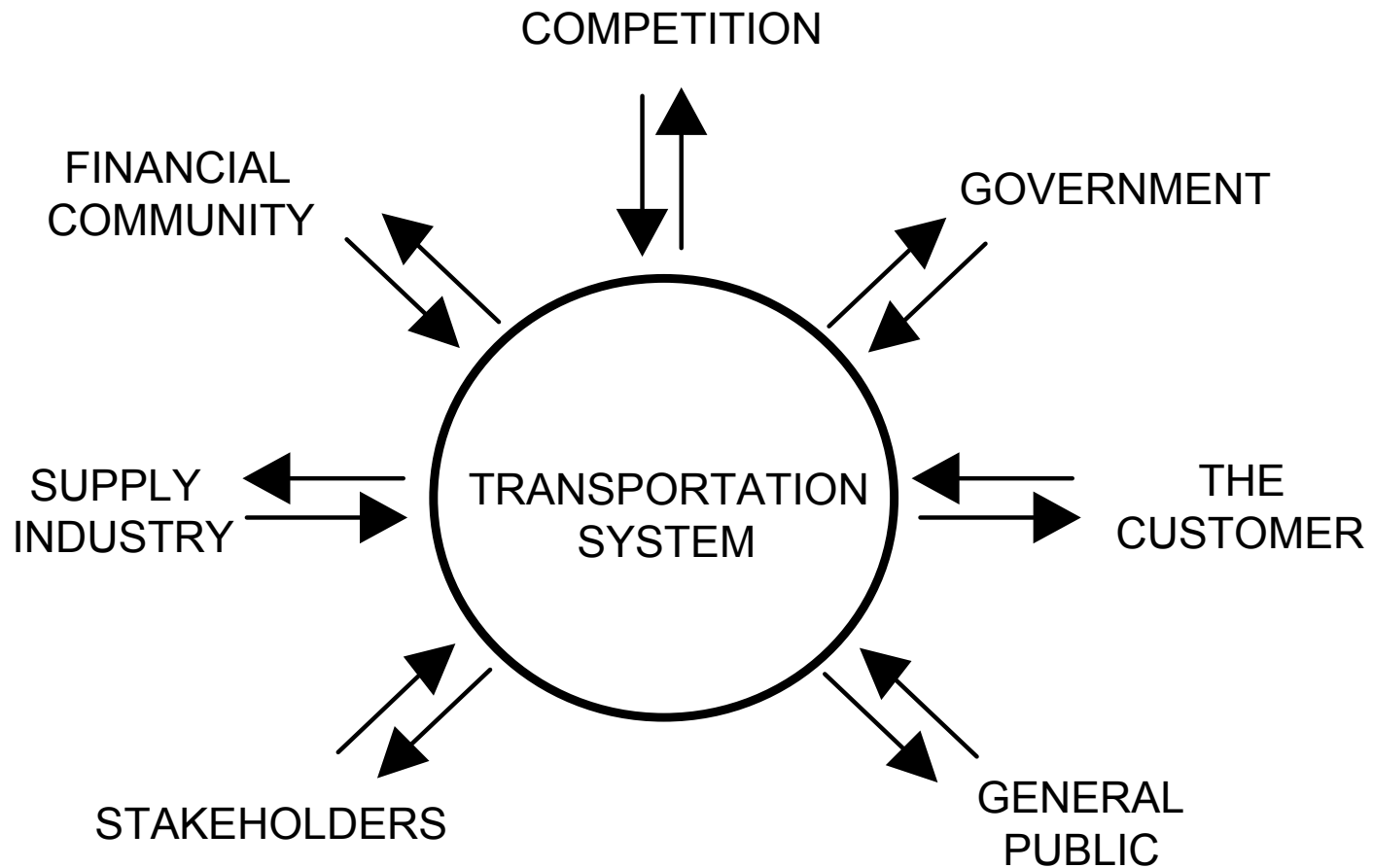


Figure 3.1

GOVERNMENT

- ◆ Taxes
- ◆ Safety regulation
- ◆ User Fees
- ◆ Financial Regulation
- ◆ Entry and Exit from Market
- ◆ Monopolies
- ◆ Provider of infrastructure
- ◆ Provider of funding

THE COMPETITION

- ◆ Intra-modal (e.g., other airlines)
- ◆ Inter-modal (rail vs. truck)
- ◆ For the consumer's money
 - ◆ Buy a house or take a vacation
- ◆ Transportation/Communication System Competition

**COMMON ERROR: VIEWING THE
COMPETITION AS STATIC**

FINANCIAL COMMUNITY

Provider of:

- ◆ Equity
- ◆ Debt

Also concerned with oversight:

- ◆ Who is on your board?
- ◆ Why are you missing your financial targets?

SUPPLY INDUSTRY

- ◆ Vehicle Providers (and their importance in the global economy) -- automobiles, airplanes
- ◆ Infrastructure Builders
 - ◆ Low-tech
 - ◆ High-tech
- ◆ Components
 - ◆ Electronics
 - ◆ Materials
- ◆ Research Community
- ◆ Insurance Industry

STAKEHOLDERS

- ◆ People/Organizations who are *not* customers or suppliers but are nonetheless concerned
 - ◆ Environmental Community
 - ◆ Abutters, e.g., of airports
 - ◆ The General Public -- concerned with quality of life, national defense, economic development, as enabled by the transportation system

THE CUSTOMER

THE CUSTOMER -- the most important external element. That's why we are in "business," but consider the difference between public sector (e.g., MBTA) and private sector (e.g., United Airlines) views of the "customer."

EXTERNAL COMPONENTS OF THE TRANSPORTATION SYSTEM

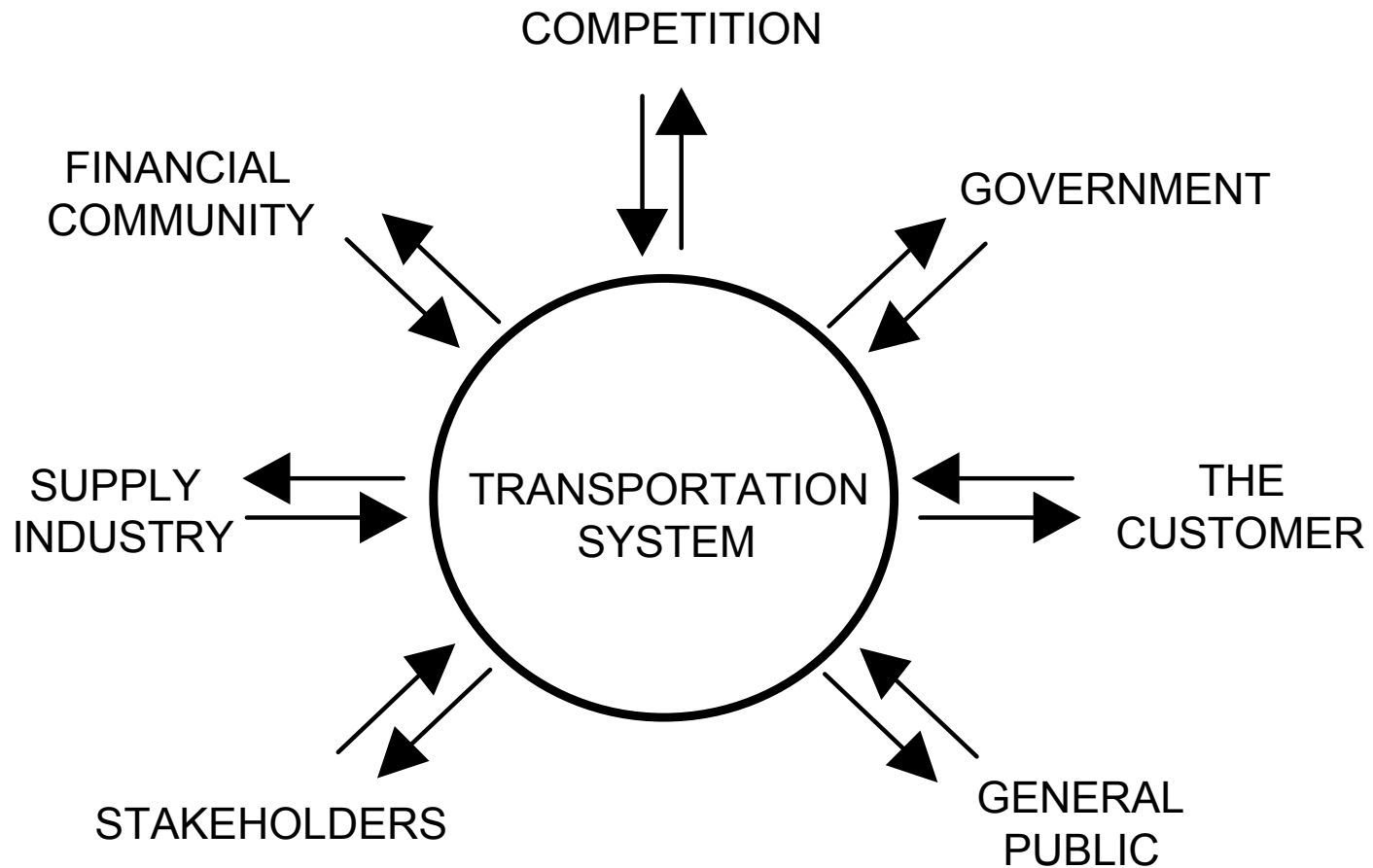


Figure 3.1

LEVEL-OF-SERVICE VARIABLES

	<u>variables</u>	<u>units</u>
TRAVEL TIME	t_t	MINUTES
ACCESS TIME	t_a	MINUTES
WAITING TIME	t_w	MINUTES
FARE	F	\$
“COMFORT”	H	“HUGS”

Figure 4.5

UTILITY

Let's define a variable "V", which is the "utility" of a traveler choice in "utils":

$$V = a_0 + a_1 t_t + a_2 t_a + a_3 t_w + a_4 F + a_5 H$$

Now, if high utility is superior, what is the sign of a_1 , a_2 , a_3 , a_4 and a_5 ? Is each one positive or negative?

MODE CHOICE

Suppose we have three possible modes of travel from Boston to New York -- air, train, auto -- and you could measure each of the level-of-service variables for each mode. We could compute the utility of each mode,

$$V_{air}, V_{train}, V_{auto}$$

and you could assume that the mode with the highest utility is the one you would choose.

MODE CHOICE

However, much modern literature in utility theory uses a probabilistic approach. For example, the probability a traveler selects the air mode is as follows:

$$P(\text{air}) = \frac{V_{\text{air}}}{V_{\text{air}} + V_{\text{train}} + V_{\text{auto}}}$$

or perhaps:

$$P(\text{air}) = \frac{e^{V_{\text{air}}}}{e^{V_{\text{air}}} + e^{V_{\text{train}}} + e^{V_{\text{auto}}}}$$

Mode Choice

This probabilistic approach is intended to reflect the fact that: 1) people have different utilities, and 2) perhaps we have not captured all the level-of-service variables in our formulation.

If we know the overall size of the market, we can approximate the mode volumes by multiplying market size by the probability a particular mode is selected.

TRAVEL TIME RELIABILITY

This depends on the *variability* in travel time between origin and destination.

Tunnel Route

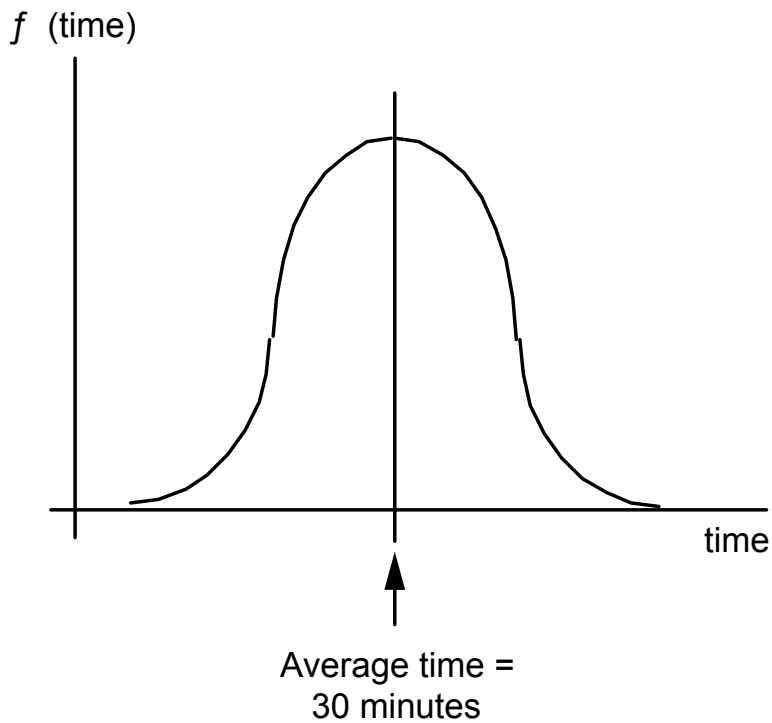


Figure 4.6

Charlestown Route

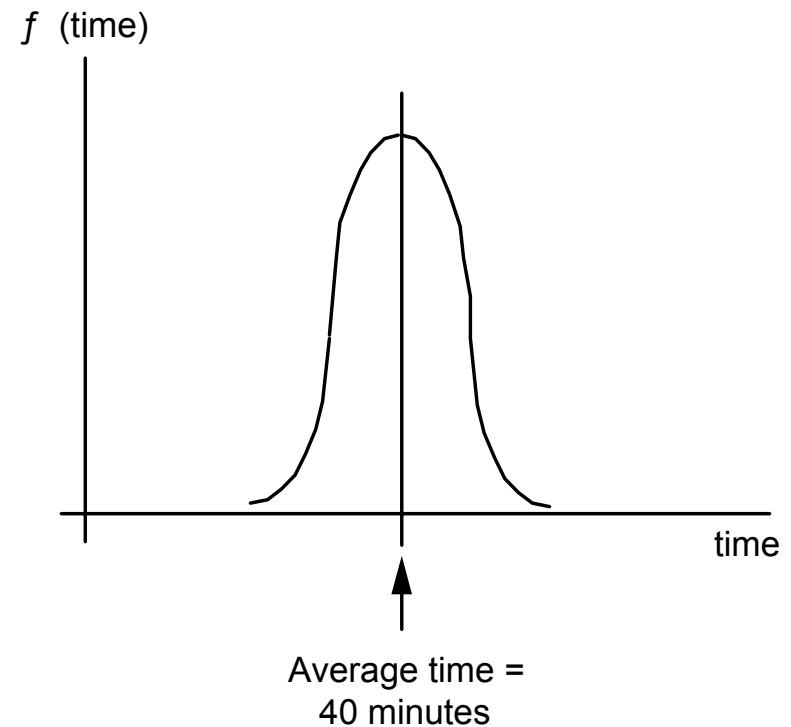


Figure 4.7

- ◆ Now, comparing these two distributions, the average travel time going through the tunnel is lower than the average travel time avoiding the tunnel. If we were making the decision based on average travel time, we would pick the tunnel route.
- ◆ But if we had a plane to catch we might say, “If I am virtually assured of getting to that plane by taking the higher average but lower variation route, that is what I’m going to do.”
- ◆ So, I chose the more “reliable” -- lower variation route -- higher average travel time route, because it virtually assures me making my air connection.

RELIABILITY

We will call variability in travel time *service reliability*. In particular systems, service reliability in travel time can be as important as average travel time. Railroad and truck systems for moving freight differ both on a reliability dimension and on an average travel time dimension.